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XXXIII. *On the Degree of Heat which coagulates the Lymph, and the Serum of the Blood; with an Enquiry into the Causes of the inflammatory Crust, or Size, as it is called: By the same.*

Read Nov. 15. 1770. **I**N the preceding paper, besides mentioning some circumstances which promote the separation of the blood, and which affect its colour, I have enquired into the causes to which its coagulation when taken from the veins is owing, and the manner in which it coagulates when at rest in the body. I shall now proceed to lay before this learned Society, an account of some other experiments which I have made upon this fluid.

Besides being coagulated when exposed to the air, the coagulable lymph, as well as the *serum*, is known to be fixed by heat; but the degree of heat has not, I think, been determined. It has been supposed to require a degree of heat almost equal to that which coagulates the *serum* *; but a much less is necessary, as will appear from the following experiments.

* Vide *Traité du Cœur*. T. ii. p. 93. Schwenk, *Hæmatolog.* p. 138.

EXPERIMENT VII.

Having found, from a number of trials, that blood, kept fluid by being mixed with neutral salts, had its lymph coagulated by a heat of 125° of Fahrenheit's thermometer, I supposed that the degree necessary for fixing it in its natural state could not be very different from this. I therefore prepared a lamp-furnace with a small vessel of water upon it; this water was heated to 125° ; and then laying bare the jugular vein of a living dog, I tied it properly, cut a piece of it out, and put it into this water: after eleven minutes, I took out the vein, opened it, and found the blood entirely coagulated; thence I concluded, that 125° , or less, was sufficient to coagulate the blood of a dog. It may be necessary to observe here, that the part coagulated was only the lymph; for the *serum* requires a much greater heat to fix it, that is heat of 160° , as will appear hereafter.

EXPERIMENT VIII.

The same experiment was repeated in such a manner, that the heat was never higher than 120° and an half; and I found, on opening the vein at the end of eleven minutes, that the lymph was entirely coagulated, even in this heat.

EXPERIMENT IX.

I next repeated the experiment, so that the heat was never higher than 114° , and was commonly at
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that degree during the eleven minutes, at the end of which time the vein being opened, the blood was found to be fluid, and in a few minutes after, being laid open to the air, it coagulated as it usually does. Now as the blood, in the last experiment but one, was coagulated, when the heat had never risen above 120° and an half; and in this experiment was fluid, though it had been exposed to a heat of 114° ; we may therefore conclude, that the coagulable lymph in the blood of a dog, in health, is fixed in a degree of heat between 114° and $120\frac{1}{2}$ of Fahrenheit's thermometer.

As to the degree of heat at which the lymph in human blood coagulates, I have not yet had an opportunity of trying it in a more satisfactory way, than with the mixture with Glauber's salt, in which state it coagulates at 125° . As we find that the human blood and that of a dog jelly nearly in the same time, when exposed to the air, I think it is probable, that the precise degree of heat at which the lymph of the human blood coagulates, is between 114° and $120\frac{1}{2}$. I have thought of making the experiment on the umbilical cord of a recent *placenta*, which is the most likely way of coming at the truth.

The degree of heat, at which the *serum* of the blood (which should not be confounded with the lymph) coagulates, is generally said to be 150° ; but from the trials I have made, I am inclined to believe it requires a greater heat to fix it. My experiments were made in the following manner.

EXPERIMENT X.

I took a wide-mouthed phial, containing *serum*, and placed a thermometer in it, and then put it into water which was kept warm by a lamp underneath; and, in making this experiment with as much accuracy as I could, I found the heat required was 160° , which is above forty degrees more than is necessary for the coagulation of the lymph.

As the blood is coagulable by heat, and as the heat of an animal body is increased in fevers, it has been supposed that the blood might be coagulated by the animal heat, even whilst it is circulating in the blood-vessels; but there is little foundation for such a supposition, since the animal heat is naturally only 98 or 100° , and in the most ardent fever is not raised above 112° .

I shall next proceed to enquire into the formation of the inflammatory crust, or *size*, as it is called.

This remarkable appearance is frequently met with in inflammatory disorders, and is formed by the coagulable lymph's being fixed, or coagulated, after the red particles have subsided. It has indeed been supposed to be formed from the *serum* of the blood; and an excellent writer on this subject seems in doubt to which it should be attributed. But that it is formed by the coagulable lymph alone, after the red particles have subsided, appears from the following experiments.

EXPERIMENT XI.

In the month of June, when the thermometer in the shade stood at 67° , I bled a man who had laboured

boured under a *phthisis pulmonalis* for some months, and at that time complained of a pain in his side. The blood, though it came out in a small stream, yet flowed with such velocity, that it soon filled the basin. After tying up his arm, I attended to the blood, and observed that the surface became transparent, and that the transparency gradually extended deeper and deeper, the blood being still fluid. That the coagulation first began on the surface, where it was in contact with the air, and formed a thin pellicle; this I removed, and observed it was soon succeeded by a second. I then took up a part of the clear liquor with a wet tea-spoon, and put it into a phial with an equal quantity of water; a second portion I kept in the tea-spoon; and I found afterwards that they both jellied or coagulated, as did the surface of the *crassamentum*, making a thick crust. On pressing with my finger that portion which was in the tea-spoon, I found it contained a little *serum*.

From this experiment it is evident, that the substance which formed the size was fluid after it was taken from the vein, and coagulated when exposed to the air; and as this is a property of the coagulable lymph alone, and not of the *serum*, there can be no doubt that the crust was formed of the former, and not of the latter.

The following experiment, made on the blood, without exposing it to the air, likewise proves the same fact.

EXPERIMENT XII.

Immediately after killing a dog, I tied up his jugular veins near the *sternum*, and hung his head over the edge of the table, so that the parts of the veins where the ligatures were might be higher than his head. I looked at the veins from time to time, and observed that they became transparent at their uppermost part, the red particles subsiding. I then made a ligature upon one vein, so as to divide the transparent from the red part of the blood; and, opening the vein, I let out the transparent part, which was still fluid, but coagulated soon after. On pressing the *coagulum*, it was found to contain a little *serum*. The other vein I did not open till after the blood was congealed, and then I found the upper part of the *coagulum* whitish like the crust in pleuritic blood*.

It has been a very generally received, opinion that inflammation thickens the blood, and makes it more ready to coagulate. Nay, some have gone so far as to say, that in those disorders where the inflammatory crust is seen, the blood is almost coagulated

* This is not the only animal that seemed to be in health, whose blood had a crust; I have seen it in others: whence I at first suspected that merely keeping the blood fluid for a little time was sufficient to produce this appearance; but I altered my opinion, on seeing, that in the greatest number of animals it did not occur; nor is it commonly met with in the hearts of those that die a violent death, though the blood remains longer fluid in such cases than it does in the basin where a size appears.

even before it is let out of the vein. Now I am persuaded from experiment, that the contrary of this is true ; or that inflammation, instead of increasing the disposition of the blood to coagulate, really lessens it ; and instead of thickening the blood, really thins it ; at least, that part which forms the crust, viz. the coagulable lymph.

In the first place, that inflammation really lessens the disposition to coagulate, will appear evident to every one who attends to the jellying of such blood as has a crust. For in all those cases the blood will be found to be longer in congealing, than it is commonly. To this opinion, I was first led by attending to the phthical patient's blood above-mentioned ; but I have since made a comparison, which seems to prove the fact. For, from a variety of experiments made on the blood of persons nearly in health, or at least who had no inflammatory complaints, and no crust on their blood, I found that the blood, after being taken from a vein, began to jelly in about three minutes and an half. The first appearance of coagulation is a thin film on the surface near the air-bubbles, or near the edge of the basin ; this film spreads over the surface, and thickens gradually till the whole is jellied, which is in about seven minutes after the opening of the vein ; and in about ten or eleven the whole is so firm, that, if the cake be cut, the gashes are immediately filled up by the *serum*, which now begins to separate from the *crassamentum*. But in those persons whose blood has an inflammatory crust, the coagulation is much later ; and in general, I believe, is latest in

those cases where the crust is thickest, and *vice versa*. The following experiments seem to prove this.

EXPERIMENT XIII.

I bled a woman who was seven months gone with child, and the blood was received into a basin. In five minutes after the vein was opened, a film first appeared; but this spread so slowly, that in ten minutes it did not cover the whole surface: in fifteen minutes it had nearly spread over the surface; but the rest of the blood was quite fluid, at least for some depth, and even in half an hour it was not so firmly jellied as it was afterwards. In this case there was a very thick and strong crust or size.

EXPERIMENT XIV.

Having bled a person with a violent rheumatic pain in his breast, the blood was received into three tea-cups, and each of them had afterwards a crust. In the first I observed the progress of the coagulation, as follows. The beginning of the coagulation was not marked, but at the end of half an hour the film was not thicker than common writing-paper; and this being removed, a little of the clear lymph was taken up with a wet tea-spoon, put into a clean cup, and was twenty minutes more in coagulating. Even at the end of an hour and an half, the whole of the blood was not jellied; for at this time I removed the film or pellicle, and took up a second portion of clear lymph with a spoon, and put it into a tea-cup, where it jellied afterwards,

terwards ; though this jelly was not indeed quite so firm as the *crassamentum* itself.

EXPERIMENT XV.

A woman, with a slight inflammation in her throat, had eight ounces of blood taken from her arm ; the blood was received into a basin, and the bleeding finished in four minutes and three quarters, when a film was begun to be formed near the air-bubbles ; in seven minutes a transparent size appeared over a considerable part of the surface which was quite fluid, whilst the rest of the blood was coagulating, there being now a very distinct red crust over the rest of the surface.

Now, from comparing these experiments with what has been observed of the coagulation of the blood, where there is no inflammatory crust or size, is it not evident that the blood remains longer fluid after being exposed to the air, and has less disposition to coagulate, in those cases where there is a size, than where there is none ? for in those cases where there was none it was found to coagulate completely in seven minutes ; but in one of the others, where the size was very thick, it was found not to coagulate completely in less than an hour and an half ?

The effect that inflammation has in lessening the lymph's disposition to coagulate, is likewise plain from the following experiment, where the blood in the heart of a dead animal seems to have coagulated very slowly.

EXPERIMENT XVI.

A dog was killed, eight hours after receiving a large wound in his neck, The wound had during this time inflamed considerably. Upon opening him next morning, when he had been dead thirteen hours, a large whitish *polypus* was found in the right ventricle of his heart; under this was a little blood still fluid, which being taken up with a teaspoon, was found to coagulate soon after being exposed to the air.

It may be proper to observe here, that in the hearts of animals which had died without any inflammation, I have found the blood entirely coagulated long before this time. And that from opening them at different times, I find it coagulates in their hearts after death, in the same gradual manner that it does in their veins, when its motion is stopt by ligatures; as related pag. 380.

In the next place, that the blood is really attenuated in inflammatory disorders, where the whitish crust or size appears, is probable from the following circumstances; first, it even seems thinner to the eye; 2dly, the red particles, or globules subside sooner in such blood, than in that of an animal in health: this seems proved by observing that in the above-mentioned experiments, where the blood was at rest in the veins, it was not covered with a crust, except in one or two instances, though in all those cases it remained longer fluid than the blood commonly does in a basin where the crust appears. And again, the blood in the heart of an animal that dies a vio-

lent death, is not generally covered with a white crust, notwithstanding it is so late in being congealed. These circumstances shew, that something more than merely a lessened disposition to coagulate is necessary for the forming of the crust or size. 3dly, The globules more readily subside in inflammatory cases, from the surface of the whole mass of blood, than they will afterwards do from the surface of a mixture with the *serum* alone, of which the following experiments are a proof; but, before I relate them, let me observe, that they were made with a view to discover, whether that remarkable appearance, the inflammatory crust, could be owing to any other cause than to the coagulable lymph's being attenuated, and having its disposition to coagulation lessened: and as the same appearance might be suspected to arise from an increased specific gravity in the red particles, or from the *serum* alone being attenuated, I endeavoured to decide the question by the following experiments.

EXPERIMENT XVII.

Into a phial, marked A, I put an ounce of the *serum* of the blood of a person, whose *crassamentum* had an inflammatory crust.

Into another, marked B, I poured an ounce of the *serum* of a person whose blood had no crust; then to each of these, I added a tea-spoonful of *serum*, loaded with the red particles of a person whose blood had no inflammatory crust or *buff*. In attending to them, I could not observe that the red particles subsided at all, sooner in the *serum* of the
blood

blood that had a crust, than they did in the *serum* of that blood which had no crust. Thence I am to conclude, that the *serum* is not attenuated in those cases where the inflammatory crust appears.

To see whether the specific gravity of the red globules was increased, I tried as follows.

EXPERIMENT XVIII.

I poured into a phial C a portion of the *serum* of the blood which had no crust; and likewise into another D a second portion of the same *serum*. I then added to C a tea-spoonful of the same *serum*, loaded with red particles from the blood which had an inflammatory crust. And into D I poured a tea-spoonful of the same *serum*, loaded with the globules of blood which had no crust. In viewing these, I could not observe that the globules of the blood which had an inflammatory crust subsided at all, sooner than those of the blood which had none; thence I am inclined to conclude, that the specific gravity of the red particles, or globules as they are called, is not increased in those cases where the crust appears. And, therefore, since that inflammatory crust or size, seems neither owing to the *serum's* being attenuated, nor to an increased specific gravity in the red particles, it is probably intirely owing to a change in the coagulable lymph. And, what seems farther to confirm this inference, in none of these experiments did the red particles subside from the surface of the *serum* in 20 minutes, though where the crust appears, they subside from the surface of the whole mass of blood in half that time; so that the

whole mass of blood seems to be thinner than the *serum* alone; or, the coagulable lymph seems to be so much attenuated in these cases, as even to dilute the *serum*, which at first sight appears a paradox.

May we not, therefore, now conclude, that in those cases where the inflammatory crust appears, the coagulable lymph becomes thinner, and its disposition to coagulation is lessened; both of which circumstances contribute to the subsiding of the red globules before the surface of the blood is coagulated, and thence give rise to this appearance, called the inflammatory crust or size *?

How contrary to the conclusion, which these experiments lead us to, are the opinions of some medical writers on this subject! How frequently do we find it said, that the blood is thicker in inflammatory disorders, where that appearance occurs; and that a large orifice is necessary to let out the vitiated blood! That a large orifice is preferable to a small one in many cases, where such blood is found, I believe is a truth: but that its advantages are owing to its letting out the thickened blood, seems improbable from what we have seen in the experiments above related: they are perhaps nearer the truth, who attribute it to the suddenness of the evacuation.

It may be proper to observe here, that this size or whitish crust, is not a certain sign of inflamma-

* This remarkable appearance might indeed be accounted for, by supposing that the lymph had ascended to the surface of the blood in those cases; but this is improbable, from considering, that, in its coagulated state, it is of greater specific gravity than the serum, and sinks in it.

tion ; it is often met with where there seems to be no such disease, in particular in the blood of pregnant women. And we may likewise observe with Sydenham, that even in those cases where the blood has a disposition to form a white crust, yet if it trickle slowly from the vein, this *size* will not appear ; for in such cases, probably, the blood begins to coagulate before the whole has done flowing, so that the agitation prevents the red particles from subsiding from the surface. There are therefore several circumstances to be taken into the account, before we judge, from the presence or want of this *size*, whether there is, or is, not an inflammation.

The whitish crust differs much in density in different cases ; in some it is extremely dense, in others it is spongy or cellular, and contains a quantity of *serum* in its cells.